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Horizontal Distribution Pattern and Carapace Size Composition of Snow Crab *Chinoecetes opilio* caught by Trap*1

(Kanikago Sogyo Kekka kara mita Zuwaigani no Bunpu to Kofuku Sosei)

by Atsushi YAMASAKI *2 and Akihiko KUWAHARA *2

in Nippon Suisan Gakkaishi (Bulletin of the Japanese Society of Scientific Fisheries) 57 (3), 439-446 (1991) (received August 30, 1990)

Horizontal distribution pattern and carapace size composition were derived for snow crab *Chionoecetes opilio* from data collected by long-line trap and Danish seine surveys conducted at 242~244 m depth in the Japan Sea off Kyoto Prefecture in May 1990. Distinct difference in horizental distribution was noted between male and female crabs, while samplings were made at the same contour in depth. Estimates of dispersion of unit patchness for mature males ranged from 100 to 200 m within a large schooling dispersion (600~1,500 m). Mature female crabs might disperse rather densely ranging from 100 to 300 m within a large school dispersing over 1,500 m and immature females ranging from 100 to 300 m within a large dispersion (400~900 m). It is surggested that growth and/or maturation of snow crab may influence horizental distribution pattern, as well as seasonal aggregation.

It was clearly showed that the carapace size compositions of crab were different between two catches by the trap and the Danish seine, which was mainly due to the differences in the frequency distribution of sub-legal male crab and mature female crab. The results showed that the trap has higher selectivity towards the large sub- legal crabs more than 80~90 mm carapace width. Estimated mean carapace width from two gears were 51.0, 67.6, 86.6, 106.9 mm for males and 51.8, 68.7, 79.0 mm for females.

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*1 Acta of the Kyoto Institute of Oceanic and Fishery Science, No. 74
*2 Kyoto Institute of Oceanic and Fishery Science, Miyazu, Kyoto 626, Japan
*3 Fisheries Research Center of the Fukui, Hyogo and Tottori Prefectures : Survey Report on Bottom Fish Resources, pp. 1 - 66 (1972)

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Ecological studies of the snow crab *Chionoecetes opilio* in the Sea of Japan have been conducted for a long time and this species is little known in terms of fisheries biological science.1) *3 Notwithstanding the above history of basic research, there is no effective resource protection policy and the stock conditions of this species are presently deteriorating. In the Kyoto Prefecture, concrete blocks have been dropped in some of the crab fishing grounds, and fishing has been prohibited in these pelagic areas in an effort at protecting the crab stocks. Since the time prohibited fishing areas were established, testing has been performed with crab traps in order to examine the crab densities in these areas. Yet, it seems that the sizes of the crabs caught during past trap tests tended on the whole to be larger than when using Danish seine. In order to compare the carapace size composition of the crabs caught in traps to that of the crabs caught with Danish seine, tests were performed almost simultaneously in May 1990, using traps and Danish seine in a 240 m deep area off the Kyoto Prefecture. We tabulated the numbers of crabs caught per trap, and attempted forecasting examinations of the so far little known horizontal crab distributions.

Materials and method

The trap tests

To know the catch characteristics of the traps, we performed tests three times, that is, on May 17-18, 21-22 and 23-24, 1990 in a 242-244 m deep pelagic area off Kyogamisaki, Kyoto Prefecture (Fig. 1). For the tests, we stretched a 5,000 m long line from west to east along the tidal current on an isobath. We attached 50 traps to the line at 100 m intervals (the trap numbers progressing from the west). The traps were submerged for 8 hours. Each time, they were cast around 4:00 AM and hauled the next day at 0:00 A.M.

The size of the crab traps used in the survey was as follows. The diameters of the bottom surface and of the entrance were respectively 130 cm and 42 cm. The height was 43 cm and the mesh size was 3 cm as recorded in detail by Sinoda et al 2). To attract the crabs, we suspended as food in the cage 5 - 6 frozen mackerels 30 cm in length. For each cage hauled aboard the

ship, we counted the number of captured males and females, and measured the sizes of their carapaces.

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With regard to the females, we used the method of Ito 3), i.e. we separated the mature individuals having encapsuled abdominal egg coils and the immature ones not having any. We measured the carapace sizes in mm units with slide calipers.

During the the May 21-22 survey, no snow crab was caught from the first to the seventh trap. No shrimp or seashell was caught either. It would seem that this happened as for some physical reason the bottoms of the traps were not resting properly on the sea floor. So, we eliminated the data of these 7 traps from our analysis.

Danish seine testing

To compare with the carapace size composition of the crabs caught with traps, we made a survey of the catch obtained with a Danish seine (swept around)). The survey of the catch obtained with the seine and the survey based on traps were conducted at about the same time, that is, one time each on May 11 and 22 respectively (one dragging). The pelagic area where the operation was conducted was practically the same as for the trap tests, and the depth was 240 - 242 m (Fig. 1). To operate the Danish seine, we used a small trawler of no more than 15 tons. The opening of the hoop net was 10 m, and the mesh size 9 knots. The area swept by the Danish seine in the present case is estimated to have been about 1.8 km . 4) Like for the trap test operations, we counted aboard the ship the females and males among the 2,513 crabs captured, and measured the carapace sizes. The method was the same used as the one used for the trap test operation.

Results

The state of snow crab capture Table 1 shows the numbers of female and male snow crabs captured in the 3 crab trap test operations. In the present trap test operations, the composition ratio of the females was larger, that is, there were 1,479 (73 %) females, and only 546 (27 %) males in the total of 2,025 snow crabs captured. Most of the females were mature, being

about double in number as compared to the immature ones. The results tended to be the roughly the same in each of the three surveys.

With the purpose of knowing the distribution of the snow crabs, and more particularly the size of the shoals, we tabulated the numbers of crabs caught per trap in each survey according to males as well as mature and immature females (Fig. 2 -4). The survey results regarding the male crabs for May 17 - 18 (Fig. 2) showed that the number of individuals captured up to near the 20th trap was smaller than the average number of captures, but that it increased from the 20th trap on. The numbers of individuals were larger than in the vicinity from the 21st to the 35th trap, and from the 40th to the 48th trap. In the survey results of May 21-22 and 23-24, aside from very small differences, the numbers of individuals caught up to trap 20 were small, but they were large from trap 20 on. From the trap 20, there tended to be a division into 2-3 smaller groups.

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In the survey May 17-18 survey results, the number of mature female crabs (Fig. 3) up to near trap 25 was greater than the average number of captured individuals, but smaller from trap 23 on. From trap 1 to trap 10, and from trap 13 to trap 25 the number of individuals captured was larger than in the vicinity. In the survey results of May 21-22 and 23-24, the number of individuals captured was larger up to trap 25, but was smaller from trap 25 on. We also noticed that up to trap 25, there tended to be a division into 3-4 subgroups. In other words, on the whole, the number of individuals captured in the first half (up to trap 25) tended to be greater, which was the opposite of the above results for the male crabs.

In the survey results of May 17-18, the numbers of captured immature female crabs were larger up to trap 6, in traps 20 - 25 and traps 40 - 48 than the average numbers of captured individuals. Similarly to the survey results of May 21-22 and May 23-24 regarding the above male crabs, up to trap 20, the numbers were smaller than the average numbers of individuals captured, but tended to be larger from trap 20 on. Moreover, from trap 20, we noted that several subgroups tended to be formed. The size of these fluctuations was about the same as for the male crabs, but smaller than for the mature female crabs. In all three surveys, the distribution patterns of the male, mature female and immature female crabs tended to be practically similar. Such crab

distribution patterns seemed to persist for at least one week, that is, from May 17 to May 24.

If one considers that the trap long line was set on the sea floor so as to make it cross snow crab shoals distributed in a variety of widths, one understands that the numbers of individuals captured per particular trap reveal the snow crab densities of the sites, and that if there is a continuation of traps with similar numbers of captured individuals, the long line runs for the same distance across a shoal. In Figs 2-4, one surveys the sizes of the shoals cut across by the long line by watching the numbers of individuals captured in each trap.

In the present article, we regard those areas where the progress in the numbers of individuals caught, reduced to 4-trap moving average (broken lines in Figs. 2-4) exceeds the total average value as high-density snow crab shoals (large aggregations). For the sake of convenience, we assume that those areas where the numbers of individuals caught per trap (solid lines in Figs. 2-4) are higher than the 4-moving average are within the above high-density shoal subgroups (small aggregations) within the above shoals. The various group sizes are consolidated in Table 2. The table shows that the male crabs form relatively large 600-1,500 m high-density aggregations, and that they form therein smaller 100-200 m aggregations having a higher density. We also see that the mature female crabs form 100-300 m small high-density aggregations within large aggregations of at least 1,500 m.

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It seems that the immature females form relatively smaller large aggregations of about 400-900 m containing smaller aggregations of about 100-300 m. In the case of immature female crabs, the difference between the large and the small aggregations was smaller than in the case of the male and the mature female crabs.

The variation coefficient of the numbers of individuals caught per trap (deviation^2/ mean value) was 4.18 - 6.42 high for the mature female crabs, followed by 1.38 - 2.09 for the male crabs, and 1,13 - 2.41 for the immature female crabs. This, in other words, means that within the adult female crab shoals, the difference in density from the vicinity is large, but that to the contrary, the differences in density are small in the case of male and of immature female crabs.

Carapace size composition of the snow crabs In order to examine whether the difficulty of capturing snow crabs with traps varies according to the size of the crabs, we compared the carapace size composition of those individuals which were captured with traps to that of those captured with the Danish seine.

Fig. 5 shows the carapace size composition of all male and female crabs captured during the three-time trap test operations. Among the male crabs, one noted three definite modes in the carapace size composition, that is, about 50 mm, 70 mm and 86 mm. The largest number of individuals belonged to the 86 mm group. The carapace size composition of the female crabs revealed a group composed mainly of immature individuals with modes of about 50 mm and 70 mm as for the male crabs, and another group composed mainly of mature individuals with a carapace size of about 80 mm. Among these, most individuals captured were about 80 mm in size. These results show that crabs with carapace sizes of 70 mm and 50 mm are more difficult to catch with traps than males and females with a 80 - 86 mm carapace size, which represent the greatest group in the catch.

Fig. 6 shows separately the carapace sizes of the female and male crabs caught with the Danish seine. The carapace size composition of the male crabs reveals two distinct modes with sizes of about 50 mm and 66 mm. The individuals with a carapace size of 66 mm were the most numerous. The carapace size composition of the female crabs revealed a group made up mainly of immature individuals whose mode showed carapace sizes of about 50 mm and 68 mm, and another group made up mainly of mature individuals whose mode showed a carapace size of about 80 mm. The largest group had a carapace size of about 68 mm.

As shown above, the sizes revealed by the various modes of carapace size composition of the female and the male individuals captured with traps and with the Danish net do practically agree. However, the sizes of the main groups caught with both types of fishing gear were different for both the females and males. This means clearly that the main group caught with traps were one molting stage ahead of the main group of individuals caught with the trawl net.

If we watch the carapace size composition of the female and male crabs caught in the present crab trap operations (Fig. 5), we note the selective capture of particular carapace sizes (molting stage). These molting stage

groups are in the case of males the group having the 86 mm carapace size mode, and in the case of females the mature group having the 80 mm carapace size mode. In short, when endeavouring to estimate the capture ratio and the stock volumes per molting stage group on the basis of the trap operations results, it is possible that the groups smaller than the above molting stage groups are underrated.

Regarding this problem, we will make a comparative examination with the carapace size composition of the crabs captured with the Danish seine. One

must assume that the frequency distribution of the composition of the various molting stage groups is regular, and estimate the mean carapace size and standard deviation for each molting stage. In the carapace size composition based on traps the modes of the small-sized molting stage groups, and in the carapace size composition based on the Danish seine the modes of the large-sized molting stage groups are not known, so the the mean carapace size and standard deviation were estimated by adding up the compositions for both types of fishing gear. We estimated the mean carapace sizes and standard deviations by the method programming the Cassie and the Taylor methods.5) We prepared the age-length key (molting stage - carapace size key) of the females and males on the basis of this mean carapace size and standard deviation. With this key, we calculated the catch ratios per molting stage of the crabs caught with the traps and of those caught with the Danish seine. Table 3 shows the results per particular type of fishing gear, for the females and the males. The mean carapace sizes of the estimated particular molting stages are 51.0 mm, 67.6 mm, 86.6 mm and 106.9 mm for the male crabs, and 51.8 mm, 68.7 mm and 79.0 mm for the female crabs. The present female crab molting stage group with the 79.0 mm mean carapace size is entirely composed of mature individuals.

While the 67.6 mm mean carapace size of the male crabs represents 64 % of all individuals captured with the Danish seine, it represents only 30 % of all individuals caught by trap. The 51.0 mm mean carapace size group represents about 20 % of all individuals caught with the Danish seine, but only 1 % of all individuals caught by trap. Conversely, the 86.6 mm and the 106.9 mm mean carapace size groups meeting the fishing target size laid down by the ministerial regulations (carapace size of 90 mm and over) amounted to only 15 % of all individuals caught with the Danish seine, but to 68 % of those caught by trap. One may say that the same tendency exists with regard to

the female crabs. In other words, the selectively captured individuals are larger with the traps than with the Danish seine.

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Discussion

Preliminary reports about the snow crab distribution characteristics

It is said that when snow crabs reach maturity they generally occupy different water depth strata according to whether they are female or male. 6) In the present test operations results, the female-male ratio was not 1:1 in May at the water depths of 242 - 244 m, but favoured heavily the female crabs. Among these females, there was a large number of mature individuals, and it is suggested that the states of distribution are different for the male, the mature females and the immature females. The pelagic region where numerous individuals are caught per trap are different for the male and the mature female crabs. There are few mature females in the regions where the males are many, and conversely there tends to be few males in those areas where mature females are numerous. If one assumes that females and males enter the traps at the same rate, it is suggested that the so-called phenomenon of separate living of the females and males is not following the traditionally accepted differences in depth, but that it could exist at the same water depth, even in relatively narrow pelagic areas not exceeding 5,000 m.

We made some examinations of the state of horizontal distribution. Adult female crabs form large aggregations of over 1,500 m. In this group, there are several subgroups of 100-300 m having a higher density. Male crabs do not form similar large aggregations, but only relatively large aggregations of about 600-1,500 m, and there are therein several subgroups with a higher density. On the whole, the immature female crab groups are small (about 400-900 m), and the density inside the group is not that much higher than in the vicinity. Thus there were among the female crabs differences in shoal size and in density as compared to the vicinity, which depends on whether the females were mature or immature. This seems to mean that male crabs and mature female crabs spread horizontally in water strata of about the same depths, that they tend to have distribution densities of a relatively large scale (patched distribution) and that there are patched distributions of smaller scale within

the above large scale, so that patches of different scales produce stratified distributions or group structures. Meanwhile, it may be that the immature female crabs form shoals in relatively small patches only.

Kobayashi and Yamaguchi 7) captured snow crabs at the Yamato reefs, and estimated that the size of the groups were 200-400 m. The survey range at that time was not wider than 700 m, and one may say that even if a larger group was existing, it would not have been possible to know it. It seems that the group size estimated by Kobayashi and Yamaguchi 7) corresponded to a small scale shoal with a higher density.

The present results suggest that even within a narrow range, the patched distribution of the snow crabs persisted for at least one week, and that the patched distribution structure was relatively stable. One points however to the fact that the present survey was conducted in May only, that in all captured mature female crabs the encapsuled abdominal egg coils were still eyeless, that around the time these eggs start producing eyes (fall - winter) the mature female crabs are concentrated in specific pelagic areas. This is why the size of the snow crab shoals and the state of distribution as well as the female-male ratios and the like might be different for different survey periods. We must therefore in the future conduct surveys at times having an important ecological meaning, such as for instance the spawning season, and also elucidate the snow crab group structure in conjunction with the ecological characteristics. More particularly, we wish to examine the relationships between the male and the mature females crabs at the mating (summer - early winter) and other similar seasons. Moreover, we also want to examine the composition of the male crabs believed to "be involved" in mating.

Carapace size composition of the captured crabs In the present survey results, there were differences in the sizes of the snow crabs captured by trap and of those captured by Danish seine. It seems that this to a certain degree explainable by the characteristics of the fishing gear and the biological characteristics of the crabs. That is, traps capture crabs by making them swarm through the smell of food. There may be differences in the speed of response to food, and in the capability of climbing on the traps, depending on the sizes of the crabs. In the case of Danish seine, there may be differences in the capability of fleeing the dragnet and net, depending on differences in the size of the crabs. The composition of the captured crabs

might differ depending on the crab size-based response to such types of fishing gear.

Whatever the reason, it seems that in the carapace composition of the crabs captured with traps, there tends with regard to actual distribution within the area where capture by trap is effective to be larger individuals. To the contrary, in the case of the Danish seine, smaller individuals tend to be more numerous. Therefore, when analyzing and evaluating in the future the carapace size composition of the individual groups of snow crabs, it should be necessary to examine which areas are adequate for capture with both types of fishing gear (the attracting area with the traps, the sweeping area with the Danish seine) as well as their fishing effectivities, and correct the respective biases.

Acknowledgment I wish to thank the entire personnel of the Kyoto Prefectural Motorboat Trawling Fisheries Cooperative for their most kind cooperation in the Danish seine test operations. I am also grateful to Dr. Masatoshi SHINODA, Head of the Kyoto Institute of Oceanic and Fishery Sciences who in the compiling of present report gave us much valuable advice. I also thank the entire personnel of the Heian-maru ship belonging to the same institute, for their hard work in the course of the trap test operations.

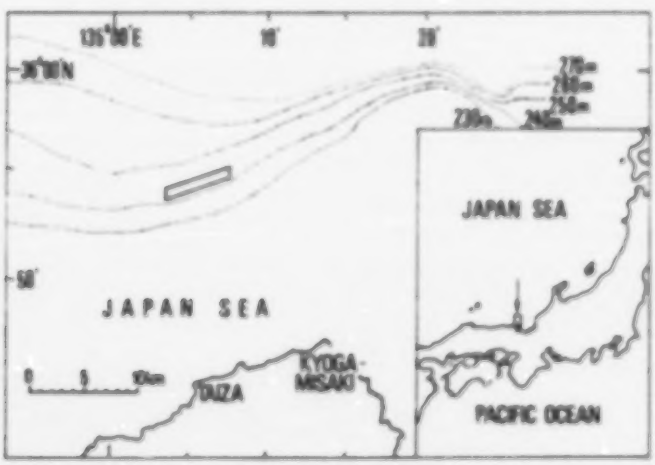

Fig. 1. Experimental fishing area by crab trap and Danish seine.

Table 1. Numbers of male, adult female and immature female crabs caught by crab trap in three experiments

Date	No. of male crab	No. of adult female crab	No. of immature female crab	Total no. of female crab	Total no. of crab
May 17-18, 1990	211 (25.2%)	466	161	627 (74.8%)	838
21-22	188 (30.2%)	319	115	434 (69.8%)	622
23-24	147 (26.0%)	277	141	418 (74.0%)	565
total	546 (27.0%)	1,062	417	1,479 (73.0%)	2,025

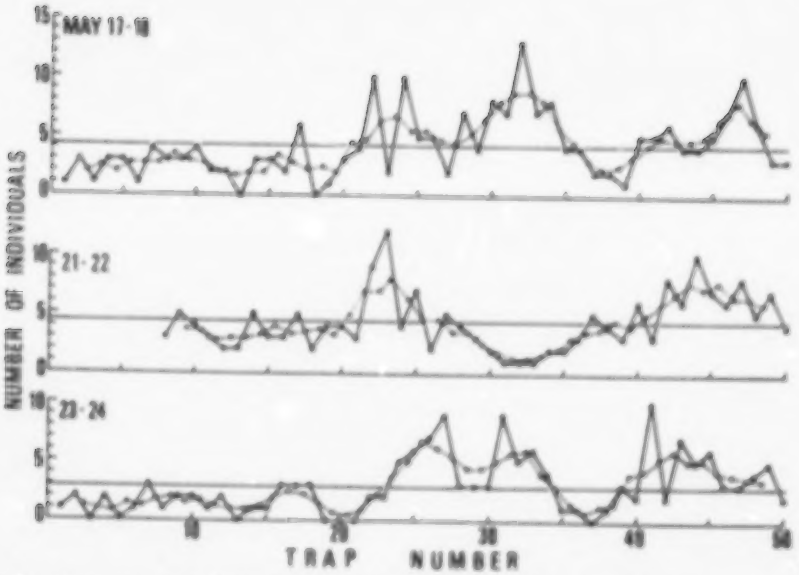

Fig. 2. Fluctuations in individual number of male crab caught by a crab trap in experimental fishing area (Fig. 1) on the 17–18th, 21–22th and 23–24th of May 1990. Solid, level and broken lines indicate number of crab in order of trap, the mean number of crab per trap and the moving average value of four traps, respectively.

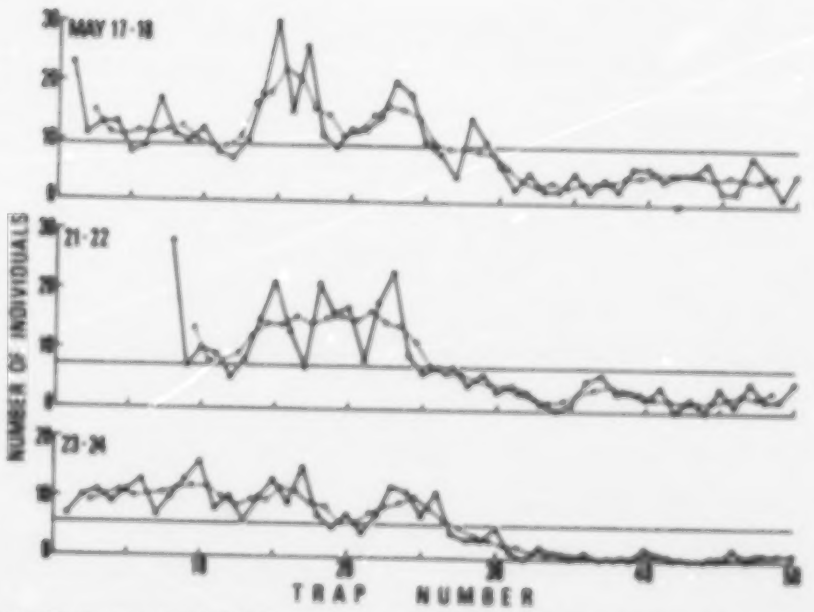

Fig. 3. Fluctuations in individual number of adult female crab caught by a crab trap in experimental fishing area (Fig. 1) on the 17–18th, 21–22th and 23–24th of May 1990. Solid, level and broken lines indicate the same as in Fig. 2.

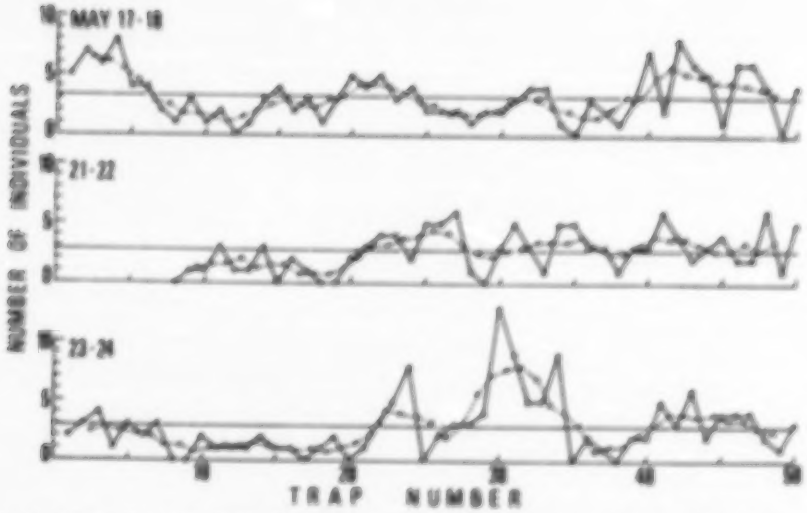

Fig. 4. Fluctuations in individual number of immature female crab caught by a crab trap in experimental fishing area (Fig. 1) on the 17–18th, 21–22th and 23–24th of May 1990. Solid, level and broken lines indicate the same as in Fig. 2.

Table 2. Estimated distances of large and small scale dispersions male, adult female and immature female crabs, basing on catch fluctuations in order of trap

	Large-scale patch	Small-scale patch
Male crab	600–1,500 m	100–200 m
Adult female crab	1,500 m–	100–300 m
Immature female crab	600–900 m	100–300 m

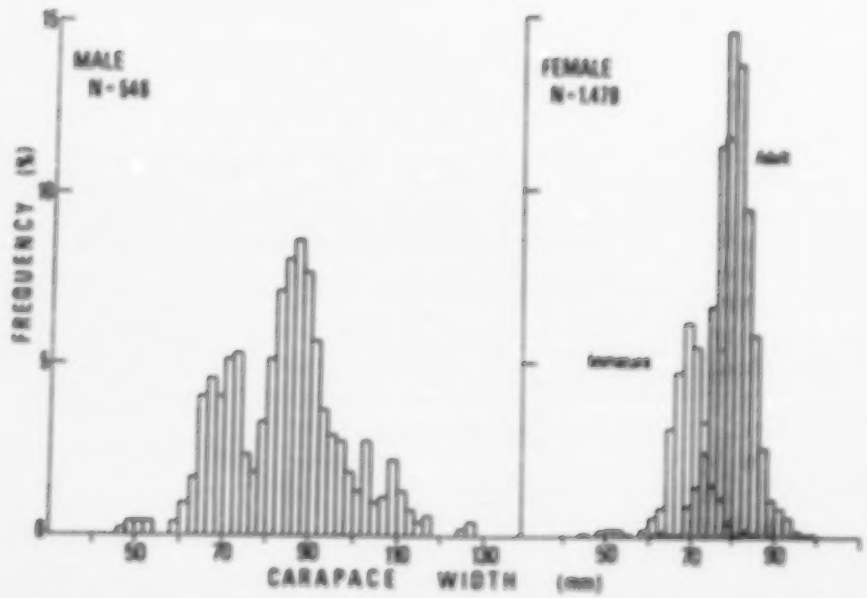

Fig. 5. Frequency distributions of carapace width of male and female crabs caught by crab trap.

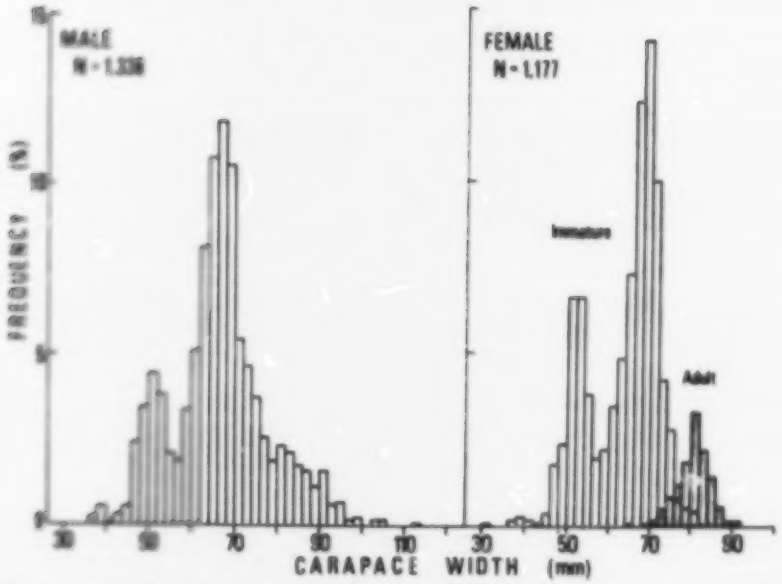

Fig. 6. Frequency distributions of carapace width of male and female crabs caught by Danish seine.

Table 3. Compositions of crab in number by molting stage of male and female crabs caught by crab trap and Danish seine

Male crab	Mean carapace width of molting stage (mm)				
	51.0	67.6	86.6	106.9	
Crab trap	0.0149	0.3010	0.5449	0.1337	0.0055
Danish seine	0.2046	0.6405	0.1484	0.0065	0
Female crab	**Mean carapace width of molting stage (mm)**				
	51.8		68.7	79.0	
Crab trap	0.0096		0.2728	0.7176	
Danish seine	0.2945		0.5789	0.1266	

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